Harmful Algal Blooms in Puget Sound: General Perspective

Rita A. Horner
School of Oceanography, University of Washington

Introduction

Worldwide, harmful algal blooms (HABs) are apparently spreading, occurring over longer time periods, and producing higher levels of toxin in shellfish. Western Washington is no exception.

In Puget Sound, HABs cause recurrent public health and economic problems and are related to paralytic shellfish poisoning (PSP), domoic acid poisoning (DAP), and mortalities of pen-reared salmonids. More potentially harmful phytoplankton species (about 20) are present in western Washington waters than in other U.S. coastal regions. The organisms that produce the toxins are common members of the phytoplankton community in Puget Sound, but little is known about their distribution, abundance, and physiological ecology.

Toxins In Shellfish

Paralytic Shellfish Poisoning (PSP)

PSP is the best known of the toxin syndromes produced by HABs and is what most people mean when they say or hear the term "red tide." The earliest recorded PSP incident occurred in 1793 when four members of Captain George Vancouver's crew became ill and one died after eating mussels harvested from Poison Cove in central British Columbia. Other deaths have occurred in British Columbia, the most recent in 1980 (Taylor and Horner, 1994). In Washington, the most recent deaths occurred in 1942 when three people died after eating PSP-contaminated mussels and clams harvested from the Strait of Juan de Fuca. High levels of PSP were found also in razor clams on the open coast near Willapa Bay (Nishitani and Chew, 1988). At that time, the management decision by the Washington Department of Health was to impose a harvest closure on all bivalve molluscs (except razor clams) from Dungeness Spit to the mouth of the Columbia River for the period 1 April–31 October. Razor clams were exempt because PSP toxin is concentrated in the digestive gland, which is removed before eating. The closure has been in effect every year since 1942.

Shellfish harvest closures are in effect also at many sites within Puget Sound during the summer and fall. In Puget Sound, no illnesses were reported from south of Admiralty Inlet before 1978. In the fall of 1978, however, high toxicity (up to 30,000 µg toxin per 100 g shellfish tissue) spread from Whidbey Basin south to Des Moines with low levels (< than 80 µg which is the harvest closure level) occurring at the Tacoma Narrows in 1979. No closures occurred in south Puget Sound until 1988 when oysters harvested from Carr Inlet were found to be toxic (up to 2000 µg) and commercial product was recalled. In 1991, Case Inlet was closed for the first time (Matter, 1994). Widespread closures occurred throughout south Puget Sound in the late fall of 1997 (see F. Cox, this volume).

A causative organism was not linked to an illness or fatality in the Pacific Northwest until 1965 (Prakash and Taylor, 1966). It is now known that members of the dinoflagellate genus *Alexandrium* (previously called *Gonyaulax* and *Protogonyaulax*) cause PSP and at least five known toxin-producing species are present in Northwest waters. These dinoflagellates occur as single cells or in chains and are able to swim, often occurring in surface waters during the day and at depth during the night. They rarely produce visible blooms.

Domoic Acid Poisoning (DAP)

Domoic acid has been found in razor clams on the Washington coast in some years since 1991, sometimes necessitating closure of the recreational razor clam harvest. It has not been a problem in Puget Sound, although blooms of the causative organism have been reported from Hood Canal (Horner et al.,

1995) and Penn Cove (R. Horner, unpubl. obs.; V. Trainer, this volume), and low numbers of cells are regularly seen in water samples collected from throughout the Sound.

This syndrome, also known as amnesic shellfish poisoning (ASP), is caused by several species in the diatom genus *Pseudo-nitzschia*. Blooms of these species may be long-lived, lasting a month or more (e.g., Hood Canal in 1995, Penn Cove in 1997), or they may be very short, lasting only a few days (e.g., Port Angeles in 1992; Grayland in 1997). The cells are long and needle-shaped and occur in chains held together by the overlapping ends of adjacent cells.

Mortalities of Finfish

Deaths of salmonids held in net pens have been known in Puget Sound at least since 1976 (Rensel et al., 1989) with major losses occurring in 1987, 1988, 1989, 1990, and 1997. HABs threaten not only current production of fish, but in the past have also been considered serious risks related to site development for new public and private net-pen facilities. The fish-killing organisms are not known to cause illness in humans.

Fish mortalities are caused by two quite different organisms. The one that receives the most attention in the press is a small, brown, flagellated organism called *Heterosigma akashiwo* that may form tremendous, visible blooms covering wide areas (see L. Connell, this volume). No specific toxin has been identified to date. The other organism includes several species of the diatom genus *Chaetoceros* that have long, barbed spines that get trapped between the gill filaments of the fish and cause excessive mucus production and eventually suffocation (Rensel, 1992). This is a physical mechanism and no toxin is produced. Visible blooms are usually not produced and as few as 5000 cells/L can cause fish deaths.

Current Knowledge

Most of our information on HABs in Puget Sound waters is based on toxins in shellfish rather than on the biology of the causative organisms. Reference will often be made to "blooms of toxic organisms" when what is meant is that toxin levels in shellfish are high. In fact, most often when toxin levels in shellfish are high, no bloom is obvious. High toxin levels may be produced by low numbers of cells, or blooms may be subsurface and not readily seen. Moreover, there may be blooms of potentially harmful species and no toxins are produced. In Puget Sound, the most spectacular discolored water is usually caused by two harmless species. Most of the time blooms are discovered only when shellfish become toxic or finfish die. Then we assume a bloom occurred, but cannot always determine where the bloom started, what environmental conditions were present when the bloom was initiated, or what conditions were necessary for toxin production. Information on the basic biology of HAB species is gradually accumulating based on field and laboratory investigations that eventually may allow better predictive capabilities in the future.

Management Strategies

Because it is rarely possible to predict when and where HABs will occur in Puget Sound, resource managers often have little warning about the presence of toxins and must close both commercial and recreational harvest areas with little notice. The closures are often widespread and may have severe economic impacts on local communities dependent on shellfisheries. Knowledge of the spatial and temporal distribution of HAB species would help alleviate this problem. As a result, phytoplankton monitoring is used at some finfish and shellfish farm sites. This is a quick, easy, but often time-consuming, way to determine if harmful species are present so that preventive measures can be taken to keep finfish alive or have shellfish tested more frequently. The availability of simple, inexpensive, accurate immunochemical probes that change color when put in sea water containing HAB species would be an ideal solution for growers, recreational harvesters, and resource managers, but their development is still in the future.

In addition to the sporadic occurrence of HABs, other factors contribute to the management problem. The toxins give no indication of their presence, cannot be destroyed by cooking or freezing, and there are no antidotes. They are very potent, thus the ability to detect them at low concentrations is critical. By the very nature of the toxins, it is difficult to design suitable detection methods. For example, PSP is not caused by one toxin, but by a suite of about 20 toxins, some of which change their structure within some shellfish. Further, depuration of toxins from shellfish may be rapid (e.g., domoic acid from mussels), or very slow (e.g., domoic acid from razor clams or PSP from butter clams). Numerous methods have been tried to increase the depuration rate, including moving toxic shellfish to areas where there is no toxin. Unfortunately, this may only increase the problem if toxin-producing cells or cysts are transferred to the clean areas with the toxic shellfish. HAB species frequently occur with harmless species and there are no measures to control or eliminate toxic species from natural phytoplankton populations. A parasitic dinoflagellate, Amoebophrya ceratii, sometimes attacks Alexandrium spp. and was thought to be a possible control (Nishitani et al., 1985), but it is not species-specific and also attacks non-HAB species.

HABs are expensive. Economic impacts may include adverse health effects, lost and/or delayed sales of product, lower prices, lost jobs, bankruptcies, less investment in aquaculture, and lost marine recreational opportunities. The 1991 domoic acid incident on the Washington coast cost local communities dependent on the recreational razor clam harvest or the commercial crab fishery between $15 and $20 million (T. Nosho, pers. comm., 1994). Included in this amount were losses of commercial oyster sales because the public feared that oysters were also toxic when they were not, the so-called “halo effect.” Costs of other blooms include $4–5 million per event for *Heterosigma*-caused fish kills and $0.5 million for *Chaetoceros*-caused mortalities. The Washington Department of Health's shellfish monitoring program costs about $0.5 million per year (WDH, pers. comm., 1997).

It is obvious that HABs are, and will continue to be, a serious economic and health problem in western Washington waters. As a result of the Washington Department of Health's toxin-testing program, there have been few confirmed illnesses from commercially harvested (testing began in 1957) or recreationally harvested (monitoring started at some sites in the 1970s) shellfish. However, as toxins spread to new areas and the harvest of non-traditional invertebrate species, e.g., moon snails, shore crabs, and barnacles, increases, more people will be at risk. Consequently, changes in management strategies may be required in order to provide adequate protection to the public.

References

Horner, R.A., Hanson, L., Hatfield, C.L., and Newton, J.A. 1996. Domoic acid in Hood Canal, Washington, USA. In Harmful and Toxic Algal Blooms, Yasumoto, T., Oshima, Y. and Fukuyo, Y., eds., pp. 127-129. Paris: Intergovernmental Oceanographic Commission of UNESCO.

Matter, A. 1994. Paralytic shellfish poisoning: toxin accumulation in the marine food web, with emphasis on predatory snails. Puget Sound Estuary Program, U.S. EPA 190/R-94-005.

Nishitani, L., and Chew, K. 1988. PSP toxins in the Pacific coast states: monitoring programs and effects on bivalve industries. J. Shellfish Res. 7:653-669.

Nishitani, L., Erickson, G., and Chew, K.K. 1985. Role of the parsitic dinoflagellate *Amoebophrya ceratii* in control of *Gonyaulax catenella* populations. In Toxic Dinoflagellates, Amderson, D., White, A, and Baden, D., eds., pp. 225-230. New York: Elsevier.

Prakash, A., and Taylor, F.J.R. 1966. A "red water" bloom of *Gonyaulax acatenella* in the Strait of Georgia and its relation to paralytic shellfish toxicity. J. Fish. Res. Bd. Canada 23:1265-1270.

Rensel, J.E. 1992. Harmful effects of the marine diatom *Chaetoceros concavicornis* on Atlantic salmon (*Salmo salar*). Ph.D. Dissertation, University of Washington, Seattle, WA. 140 pp.

Rensel, J.E., Horner, R.A., and Postel, J.R. 1989. Effects of phytoplankton blooms on salmon aquaculture in Puget Sound, Washington: initial research. Northw. Environ. J. 5:53-69.

Taylor, F.J.R. and Horner, R.A. 1994. Red tides and other problems with harmful algal blooms in Pacific Northwest coastal waters. In Review of the Marine Environment and Biota of Strait of Georgia, Puget Sound, and Juan de Fuca Strait, Wilson, R.C.H., Beamish, R.J., Aitkens, F., and Bell J., eds., pp. 175-186. Proc. BC/Washington Symposium on the Marine Environment, Jan. 13–14, 1994. Can. Tech. Rep. Fish. Aquat. Sci. 1948.